frontiers | Frontiers in Education

TYPE Original Research
PUBLISHED 02 April 2025
DOI 10.3389/feduc.2025.1418184

OPEN ACCESS

EDITED BY
Dillip Das,
University of KwaZulu-Natal, South Africa

REVIEWED BY
Hideyuki Kanematsu,
Osaka University, Japan
Wunhong Su,
Hangzhou Dianzi University, China
Ririn Ambarini,
Universitas PGRI Semarang, Indonesia

*CORRESPONDENCE
Jorge Valverde-Rebaza
jvalverr@tec.mx

RECEIVED 16 April 2024
ACCEPTED 10 March 2025
PUBLISHED 02 April 2025

CITATION
Valverde-Rebaza J, Rodrigues de Góes F, Noguez J and Da Silva NC (2025) Skill-based employment taxonomy in the global IT industry 5.0. *Front. Educ.* 10:1418184. doi: 10.3389/feduc.2025.1418184

Skill-based employment taxonomy in the global IT industry 5.0

Jorge Valverde-Rebaza[1,2]*, Fabiana Rodrigues de Góes[2], Julieta Noguez[1] and Nathalia C. Da Silva[2]

[1]School of Engineering and Science, Tecnologico de Monterrey, Monterrey, Mexico, [2]Department of Scientific Research, Visibilia, Brazil

Introduction: The Information Technology (IT) sector, a key driver of Industry 4.0 and the transition toward Industry 5.0, continues to demonstrate resilience in the face of prevalent global challenges, including the ongoing COVID-19 pandemic and persistent talent shortages. The prominence of IT roles in the global job market highlights the need for a unified framework that efficiently identifies and categorizes IT jobs. While the International Labour Organization (ILO) has introduced the International Standard Classification of Occupations (ISCO) for job classification on a global scale, it lacks the necessary granularity for the rapidly evolving IT landscape.

Methods: Efforts to bridge the previous granularity issue often fall short due to country-specific labor market peculiarities. To address this gap, this work introduces a novel hierarchical taxonomy for classifying IT jobs within the broader framework of ISCO-08. Following meticulous data labeling and clustering, the development of the Bee-inspired Employment and Expertise Taxonomy (BEET) was a collaborative effort between the HR team, data scientists, analysts, and the authors of this article. A lot of public job postings were gathered that encompass a diverse range of vacancies within the IT sector, spanning from October 2023 to February 2025. Using insights from the clustering results, the team worked to identify distinct patterns and commonalities across IT job roles. Our taxonomy consists of five major groups, further divided into 15 sub-major groups and 35-unit groups. The proposed taxonomy has the potential to not only categorize diverse IT roles with precision but also forecast workforce demands effectively.

Results: Key insights suggest that this hierarchical approach could significantly aid in workforce demand forecasting and provide valuable guidance to educators in shaping programs that prepare professionals for the challenges of Industry 5.0. Furthermore, by aligning educational efforts with the evolving needs of the global IT market, our proposal offers a robust framework for both analysts and educators, providing strategic insights essential for future workforce development in the rapidly advancing.

Discussion: The development of the BEET taxonomy marks a significant advancement as a framework for IT job classification, offering a comprehensive and adaptable tool aligned with the evolving demands of the technology sector in the era of Industry 5.0. By leveraging the BEET framework, we can gain deeper insights into the dynamics of the IT labor market, enabling more targeted and impactful research. However, some limitations should be noted, as the dataset used to develop BEET consists exclusively of English-language job postings from various countries, which may introduce linguistic and regional biases. Additionally, certain niche or emerging roles that are less frequently advertised online may be underrepresented in the taxonomy.

KEYWORDS

IT employment taxonomy, Industry 5.0 skills, job classification, information technology market, STEM skills, educational innovation, higher education, professional education

1 Introduction

In today's globalized world, technology plays a pivotal role in transforming the job market, driving unprecedented changes in the workforce through an increasing synergy between jobs, technology, and education (Dobslaw et al., 2023; Siddique et al., 2024). Over the past four decades, technological advancements have significantly influenced global employability and productivity, underscoring the importance of education in preparing individuals for technology-driven job markets. This interconnected relationship has particularly strengthened the Information Technology (IT) sector (Castro Silva and Lima, 2017; Hötte et al., 2023; Koo and Le, 2024), which has demonstrated resilience in addressing global challenges such as the COVID-19 pandemic and talent shortages by emphasizing human-centric technologies (Apatsidis et al., 2021; König and Seifert, 2022; Akah et al., 2022; Oikonomou et al., 2023; Hötte et al., 2023). As the industry continues to evolve, the transition from Industry 4.0, which focused on automation and data-driven efficiency, to Industry 5.0, emphasizes human-technology collaboration, innovation, and sustainability. This shift introduces new dynamics in the IT job market, where individuals now face the challenge of blending technical skills with creativity and ethical considerations to develop socially responsible solutions (Wang et al., 2020; Fettach et al., 2022).

In this context, IT roles have come to increasingly dominate the global job market (World Economic Forum, 2023). Nonetheless, a significant gap persists in effectively organizing IT-related skills to facilitate accurate job classification (Uter, 2017; Napierala and Kvetan, 2023; Azofeifa et al., 2024). Therefore, the need for a unified framework that accurately identifies and categorizes IT skills has never been more critical.

Current frameworks, such as the International Standard Classification of Occupations (ISCO) developed by the International Labour Organization (ILO), establish a global baseline for job classification. Over the years, ISCO has been revised multiple times to adapt to the evolving structures of occupations worldwide. The two most recent iterations, ISCO-88 and ISCO-08, have notably influenced the classification landscape. ISCO-88, launched in 1988, offered a comprehensive update reflecting the dynamic nature of employment. However, acknowledging the necessity for further refinement and alignment with contemporary labor market trends, ISCO-08 was developed and published in 2008. This latest version incorporates enhanced methodologies and additional dimensions, resulting in a more nuanced classification system that more effectively captures the complexities of modern occupations (International Labour Organization, 2023).

The unique characteristics of skills and job offerings in each country have driven national organizations to adapt and utilize ISCO-08 as a foundational framework. These initiatives aim to develop comprehensive classifications that encompass all forms of employment. An example is the Mexican National Occupation Classification System (SINCO) (Instituto Nacional de Estadística y Geografía, 2019), which integrates additional dimensions of skill specialization which encompass factors such as "level of responsibility" and more detailed elements pertaining to the nature of goods or services produced, such as "modality of sale". Similarly, Canada's National Occupational Classification (NOC) (Statistics Canada, 2021) incorporates "Training, Education, Experience, and Responsibilities" (TEER) levels along with skill specialization to more precisely categorize occupations. The NOC framework addresses the challenge of overlapping skill specializations by establishing separate groups based on TEER level and specialization. In Australia and New Zealand, the Australian and New Zealand Standard Classification of Occupations (ANZSCO) (Australian Bureau of Statistics, 2022) uses a combination of skill level and skill specialization considerations to enhance the clarity and usability of the occupational classification.

The existing frameworks, including ISCO-08, SINCO, NOC, ANZSCO, and others, while comprehensive in scope, have limitations when applied to the IT sector. These frameworks typically emphasize job classification without sector-specific specialization, which limits their applicability to the IT sector, which demands a more nuanced approach. To the best of our knowledge, the only prior proposal for a specific job classification framework focused on the IT sector is the work by Melkumyan (2006). Other efforts have primarily aimed at organizing IT domains, such as the 2012 ACM Computing Classification System (CSS) (Association for Computing Machinery, 2012), or focused on specific IT segments, including Software Engineering (Papoutsoglou et al., 2019), Requirement Engineering (Wang et al., 2018; Moravánszky, 2024), Human-Computer Interaction (Butiurca and Zancanaro, 2021), Data and Business Analytics (Barefah, 2024), among others. Although there are some works in which efforts are made to discover patterns between skills that help classify jobs (Valverde-Rebaza et al., 2018; Ghosh et al., 2020; Choi et al., 2021; Ternikov, 2022; Baldwin et al., 2022; Fettach et al., 2022; Siswipraptini et al., 2023, 2024; Senger et al., 2024; Alharbi and Al-Alawi, 2024; Azofeifa et al., 2024), there is a strong gap for a more refined classification system that accurately reflects the diverse IT landscape.

In this article, we introduce the ***B**ee-inspired **E**mployment and **E**xpertise **T**axonomy* (**BEET**), a hierarchical framework designed to classify IT jobs within the ISCO-08 structure. In accordance with ISCO guidelines, BEET prioritizes the hard skills required for task execution as well as the expected level of seniority, irrespective of how these skills are acquired. Our taxonomy is built on a comprehensive analysis of requisites and technical skills extracted from our own dataset of global IT job postings, which we meticulously collected between 2023 and 2025. An initial version of BEET was previously published (Valverde-Rebaza et al., 2024). In this manuscript, we present the enhanced version BEET v2025-rev2, which incorporates feedback and insights from the initial release, broadening its applications and improving classification accuracy.

We anticipate that BEET will help analysts forecast the demands of the workforce and HR professionals in better aligning applicants with job opportunities, streamlining the recruitment and selection process for greater efficiency. Furthermore, our proposal offers to educators valuable guidance to prepare professionals for face the challenges anticipated with Industry 5.0.

The structure of this article is organized as follows: Section 2 provides a comprehensive review of all the steps that led to the construction of the framework we propose, including verification and validation processes. Section 3 details the complete structure of BEET, including examples of the classification of some vacancies and reporting potential overlaps between unit groups.

Section 4 concludes our research with a discussion of our findings, highlighting the implications and potential impact of this research. Finally, Section 5 summarizes the key findings and highlights potential directions for future research.

2 Materials and methods

In this section, we outline all the steps related to data processing that allowed the development of our IT employment taxonomy.

2.1 Data collection

We gathered public job postings that encompass a diverse range of vacancies within the IT sector, spanning from October 2023 to February 2025. Our dataset includes job postings from companies of varying sizes, including small, medium, and large enterprises, located across the globe, with a focus on Europe and America. Additionally, we considered only job postings published in English.

The selection of job postings was based on several criteria to ensure a representative and comprehensive dataset. We focused on roles that are predominantly tech-centric and sought to cover a broad spectrum of IT positions, from entry-level to senior roles. The inclusion criteria required that postings explicitly list requisite technical skills relevant to Industry 5.0, ensuring relevance to our taxonomy development. Furthermore, the selection process emphasized diversity in both the geographical origin of the postings and the industry sectors they represent, although the dataset is primarily composed of postings from the technology, finance, and healthcare industries.

A total of 1,780 IT job offers were collected using web crawlers specifically designed for this purpose. Importantly, this collection process was conducted directly on the companies' public websites, following thorough verification of their data policies, to minimize bias. Additionally, relying on web-scraped data may result in the underrepresentation of companies with lower online visibility, as well as job postings that are less popular or less frequently advertised.

Manual search and collection were also carried out in specific cases. For example, after defining our taxonomy, there was an effort to balance the IT jobs dataset to avoid excessive imbalance, as some job categories might naturally occur more frequently than others. Thus, if there was a low number of job offers collected for a specific job category, then more job postings from that category were manually searched on the web for subsequent collection. Additionally, to further reduce bias, a process of anonymizing company names was conducted. This ensures that analysis and insights derive strictly from job content rather than company identity or reputation.

2.2 Data labeling

Our data labeling process involved a team of three Human Resources (HR) professionals, each with extensive experience in recruitment and selection processes within the IT sector, who meticulously reviewed the collected vacancies. These professionals applied labels at two levels of granularity. At the first level, they categorized job offers based on potential areas of Computing using the 2012 ACM Computing Classification System (CSS) (Association for Computing Machinery, 2012).

The choice of ACM CSS was driven by its status as a well-known and widely used framework within the academic IT community, providing comprehensive coverage of computing domains through its semantic vocabulary. These qualities make it particularly effective at capturing the broad spectrum of IT roles. As a poly-hierarchical ontology, the ACM CSS offers flexibility and depth in categorizing computing topics, accommodating multiple classifications for positions that span various areas of expertise. For example, a job offer for a front-end developer might be categorized under both "Software and its Engineering" and "Human-centered computing". Regular group discussions and periodic meetings were held to align understanding, resolve ambiguities, and ensure consistent application of labels across all job postings.

At the second level of granularity, more specific labels were assigned to define job offers based on the main activities to be performed. For instance, job offers seeking database administrators or Oracle database specialists were both categorized under the "database" classification.

This thorough process resulted in a final dataset comprising 389 labeled job offers. Notably, this dataset is characterized by its balanced distribution across job categories, with each second-level category containing approximately 10 job offers in average.

2.3 Job skills understanding with NLP and machine learning assistance

In our data analysis, we employed natural language processing (NLP) techniques to create representations of job vacancies, focusing on skills, technology knowledge, and technical requirements requested (Valverde-Rebaza et al., 2018; Baldwin et al., 2022; Senger et al., 2024; Jose Gonzalez-Gomez et al., 2024). Subsequently, we employed an agglomerative hierarchical clustering algorithm, a widely-used approach for unsupervised clustering, to group and analyze the labeled dataset.

In the data preprocessing stage, the job descriptions were cleaned using a custom preprocessing function, which included basic text normalization, such as converting text to lowercase, removing punctuation, and eliminating non-relevant characters. Following the cleaning process, we converted the job descriptions into numerical features, which included the removal of stop words. This step also accounted for common words that appeared frequently but carried little semantic weight, reducing noise in the data.

For feature extraction, we relied on the TF-IDF representation of the text, capturing important terms that could distinguish job roles. After that, we applied the Average Linkage Hierarchical Clustering (ALHC) algorithm (Siswipraptini et al., 2023). Here, we adopted Ward's method as the criterion for selecting the pair of clusters to merge at each step, based on the optimal Euclidean distance. By setting a Ward distance threshold of 1.72, we automatically obtained 32 clusters formed based on textual similarity extracted from job descriptions. These 32 clusters were

further hierarchically grouped by ALHC algorithm into 9 broader groups, distinguished by different colors in Figure 1. This figure highlights some of the most relevant hard skills appearing in the leaf nodes of the clustering structure.

Here, it is important to consider that one of the key benefits of ALHC algorithm is its ability to capture hierarchical structures in the data, allowing for a deeper understanding of the relationships and similarities among job descriptions. Additionally, it does not require the specification of the number of clusters beforehand, offering flexibility in identifying meaningful groupings based on the dataset's intrinsic characteristics.

Therefore, to assess the quality of the clustering results, we computed three widely used validation metrics: Silhouette Score, Davies-Bouldin Index, and Calinski-Harabasz Score. The obtained Silhouette Score of 0.0470 reflects the inherent complexity of job descriptions in the IT sector, where overlapping skill requirements and shared technology stacks make strict cluster separability challenging. The Davies-Bouldin Index of 3.3704 indicates a certain degree of similarity between some clusters, which is expected given the frequent co-occurrence of skills across different job roles. Meanwhile, the Calinski-Harabasz Score of 2.9119 suggests that, while the clusters exhibit some dispersion, they still provide a structured representation of the underlying data. These results align with the nature of job postings, where distinctions between roles are often nuanced rather than sharply defined. More importantly, the clustering serves as a strong foundation for human experts to refine the classification, helping to uncover meaningful groupings and better distinguish job categories based on domain knowledge.

2.4 Building BEET: a new skill-based IT employment taxonomy

Following meticulous data labeling and clustering, the development of the Bee-inspired Employment and Expertise Taxonomy (BEET) was a collaborative effort between the HR team and the authors of this article. Using insights from the clustering results, the team worked to identify distinct patterns and commonalities across IT job roles.

Our HR team, leveraging their extensive industry experience, played a crucial role in aligning the taxonomy with real-world job market demands. Their expertise was essential in interpreting the clustering outcomes (presented in Section 2.3) and refining the initial clusters into well-defined categories that accurately represent the diversity of skills and roles in the IT sector. Following this validation, the authors focused on integrating theoretical frameworks and ensuring compliance with academic rigor and ISCO-08 standards. Through a series of collaborative workshops and iterative refinement sessions, the team structured BEET to maximize both its applicability and robustness.

The final taxonomy consists of 35 unit groups, expanding upon the 32 clusters identified through the ALHC algorithm. These unit groups are further organized into 15 sub-major categories, derived from the 9 groups initially formed. Ultimately, these categories are consolidated into 5 main groups. A detailed explanation of BEET is provided in Section 3.

To assess BEET's consistency, we conducted an expert agreement evaluation with a panel of five HR professionals specializing in IT recruitment. Each expert independently classified a random sample of 100 job postings into the appropriate BEET unit groups. The reliability between raters was measured using Cohen's kappa coefficient, a widely accepted metric for categorical classification tasks. The resulting kappa score of 0.78 indicates substantial agreement among experts, demonstrating the reliability of BEET as a classification framework. Disagreements occurred primarily in roles with overlapping skill requirements, highlighting the importance of clear definitions of categories.

2.5 Integration and practical implications

BEET demonstrates significant potential for integration into existing recruitment and educational systems, thereby improving workforce planning, talent acquisition, and curriculum development. Since 2021, various versions of BEET have been incorporated into BeeNet, a web-based recommendation system designed to assist HR teams in Brazilian companies of different sizes in more effectively matching candidate profiles with job openings during the recruitment and selection process for IT professionals (FAPESP, 2019).

Continuous feedback from the BeeNet system has contributed to the systematic refinement of BEET. As a result, BEET has evolved into a robust taxonomy aimed at improving the classification and analysis of IT jobs while facilitating better alignment between educational programs and industry demands within the context of Industry 5.0. One of BEET's key strengths lies in its strong alignment with established classification systems such as ISCO-08 and ACM CSS, which enhances its adoption and interoperability.

The well-recognized semantic vocabulary of ACM CSS further supports BEET in accurately classifying and representing IT roles across various domains. Thus, BEET's structure, influenced by ACM CSS, accommodates a broad range of computing topics with a flexible and comprehensive categorization framework. Furthermore, BEET's integration with the ISCO-08 framework enhances the granularity and specificity of IT job classifications, addressing common limitations found in existing classification standards. This alignment ensures that BEET not only complements international standards but also extends them by providing a more detailed categorization tailored to the rapidly evolving IT sector.

2.6 Validation processes

BEET validation was conducted through an extensive pilot test, and iterative refinement process from 2020 to 2024. During its development, each component of BEET was meticulously evaluated and incorporated only after receiving approval from the entire team responsible for its creation. This team consisted of HR professionals, academic experts, and industry advisors, whose diverse perspectives ensured BEET's practical relevance and academic robustness.

Progress in BEET's development was assessed through a series of pilot tests that applied the taxonomy to real-world job postings and recruitment scenarios. These tests aimed to replicate actual

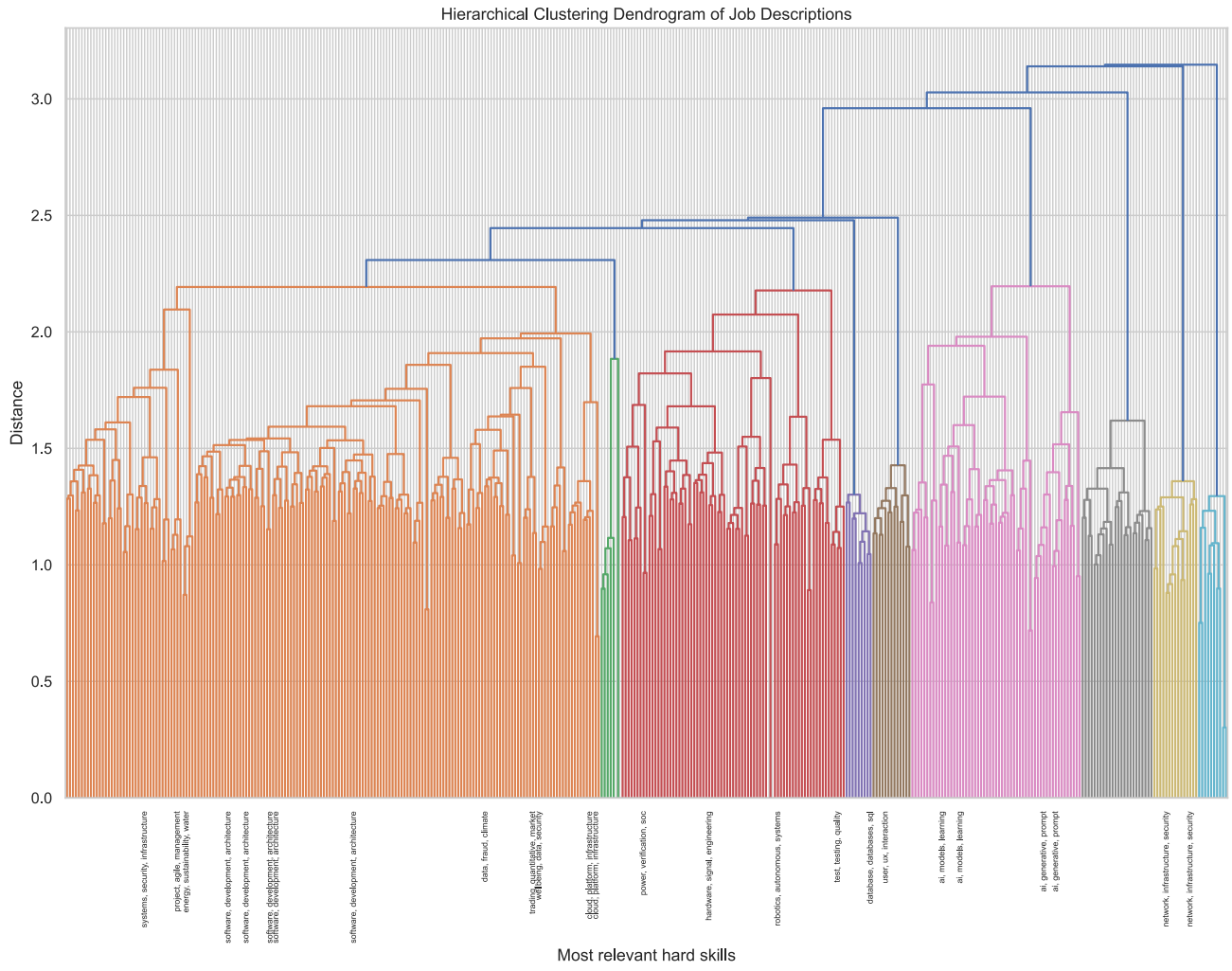

FIGURE 1
Hierarchical clustering dendrogram obtained from job vacancy descriptions.

conditions and gather detailed feedback from users, including HR professionals from various companies actively engaged in candidate selection processes within the IT job market.

Regular feedback sessions from the team and insights from pilot testing were crucial for validating our taxonomy. They facilitated the resolution of any inconsistencies or gaps in the classification framework. Furthermore, the iterative nature of the validation ensured that BEET not only reflects best practices but also adapts to new roles and technologies emerging in the IT sector. Consequently, BEET is equipped to provide accurate and comprehensive classifications that align with its foundational goals within the context of Industry 5.0.

3 Bee-inspired Employment and Expertise Taxonomy (BEET)

As result of the process detailed in Section 2, in this section we present a comprehensive overview of BEET and its categories. BEET is formed by five major groups (MG), which are further divided into 15 sub-major (SM) categories and 35 unit groups (UG), as illustrated in Figure 2.

3.1 MG1–System

Professionals in the System major group play a pivotal role in shaping the foundational elements needed for the design and implementation of robust and reliable systems adhering high safety and sustainability standards. These professionals ensure that systems are designed to meet current needs while being adaptable for future advancements, balancing performance, efficiency, and environmental impact. Thus, MG1 is formed by two sub-major groups: Micro and Small Systems (SM1) and Macro Systems (SM2).

3.1.1 SM1–Micro and Small Systems

The Micro and Small Systems sub-major group encompasses the design, development, and integration of compact electronic systems and devices. Jobs in this group require professionals

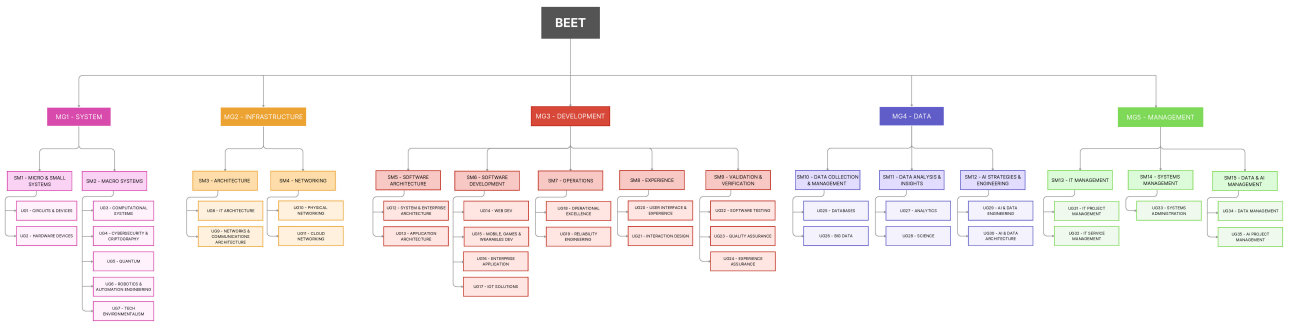

FIGURE 2
Graphical depiction of BEET, the hierarchical taxonomy proposed for classifying IT job roles.

to have the ability to create efficient but miniaturized solutions that meet the demands of modern applications, ranging from consumer electronics to industrial automation. Professionals leverage their expertise in circuit design, hardware integration, and system optimization to deliver innovative products that enhance functionality while minimizing size and power consumption. Thus, SM1 consists of 2 unit groups: Circuits and Devices (UG1) and Hardware Integration (UG2).

3.1.1.1 UG1–Circuits and Devices

This unit group specializes in the design and development of electronic circuits and devices. Professionals in this group are responsible for creating the foundational components that enable the functionality of micro and small systems. They work on various technologies, including analog, digital, and mixed-signal circuits, ensuring that devices operate reliably and efficiently. Key responsibilities include:

- Circuit design: develop and simulate electronic circuits using software tools to ensure optimal performance and reliability.
- Component selection and prototyping: choose appropriate electronic components based on specifications, performance requirements, and cost considerations to build and test prototypes of circuits and devices to validate designs and identify potential issues.
- Testing and Validation: Conduct rigorous testing of circuits and devices to ensure compliance with industry standards and specifications.

Relevant job roles include: Circuit Design Engineer, Embedded Systems Engineer, Electronics Technician, Digital Design Engineer, PCB Design Engineer, Mixed-Signal Design Engineer, and others.

3.1.1.2 UG2–Hardware Integration

This unit group is dedicated to the integration of various hardware components into cohesive systems. Professionals in this area focus on ensuring that different hardware elements work together seamlessly, optimizing performance and functionality. They are involved in the assembly, testing, and troubleshooting of integrated systems, ensuring that all components function as intended. Key responsibilities include:

- System integration: combine various hardware components into a unified system, ensuring compatibility and functionality.
- Testing and troubleshooting: conduct tests on integrated systems to identify and resolve issues related to hardware interactions and performance.
- Configuration management and performance: manage hardware configurations and ensure that all components are correctly set up for optimal performance to improve efficiency and reliability.
- Collaboration with software teams: work closely with software engineers to ensure that hardware and software components are effectively integrated.

Relevant job roles include Hardware Integration Engineer, Hardware Support Engineer, Field Application Engineer, Field Service Engineer, and others.

3.1.2 SM2–Macro Systems

The Macro Systems sub-major group encompasses the study, design, and management of larger-scale or impactful systems, which can be simple or complex, influencing broad operational contexts. Jobs in this group require professionals to have the ability to understand the interactions between different system elements, ensuring their effective operation. Thus, SM2 consists of 5 unit groups: Computational Systems (UG3), Cybersecurity and Criptography (UG4), Quantum (UG5), Robotics and Automation Engineering (UG6), and Tech Environmentalism (UG7).

3.1.2.1 UG3–Computational Systems

This unit group focuses on the design, development, and optimization of computational systems that process and analyze data through established logic and methodologies. It encompasses a range of technologies and applications, including algorithm development, numerical methods, and software engineering, aimed at solving complex problems across various domains. Key responsibilities include:

- Algorithm development: design and implement algorithms to solve specific computational problems.

- Performance optimization: analyze and optimize the performance of computational systems to ensure efficiency and scalability.
- Numerical analysis: apply numerical methods to solve complex equations and problems in physics.
- Simulation and modeling: create simulations and models to represent complex systems and predict their behavior.
- Interdisciplinary collaboration: work collaboratively with researchers and engineers across disciplines, integrating computational techniques into diverse applications.

Relevant job roles include Algorithm Engineer, Simulation Scientist, System Analyst, Computational Analyst, Computational Scientist, Computational Physicist, Applied Research Scientist, and others.

3.1.2.2 UG4–Cybersecurity and Criptography

This unit group focuses on the technical aspects related to the protection of systems and data from cyber threats, the implementation of cryptographic techniques, and the development of secure systems. It encompasses a range of specialized practices aimed at ensuring the integrity, confidentiality, and availability of information in digital environments. Key responsibilities include:

- Threat analysis: identify, analyze, and assess potential cyber threats and vulnerabilities in systems and networks.
- Cryptographic implementation: develop and implement cryptographic algorithms and protocols to secure data transmission and storage.
- Security architecture design: design and evaluate security architectures that protect against unauthorized access and data breaches.
- Incident response and forensics: conduct technical investigations of security incidents and breaches, analyzing evidence to determine the cause and impact.
- Vulnerability assessment: perform technical assessments and penetration testing to identify and remediate vulnerabilities in systems and applications.

Relevant job roles include Cybersecurity Engineer, Cryptography Specialist, Security Researcher, Penetration Tester, Cybersecurity Researcher, Information Security Specialist, Cryptanalyst, and others.

3.1.2.3 UG5–Quantum

This unit group focuses on the study and application of quantum technologies and principles, including quantum computing, quantum communication, and quantum cryptography. Professionals in this group are tasked with leveraging quantum mechanics to develop innovative solutions that can outperform classical systems in terms of speed, security, and efficiency. Key responsibilities include:

- Quantum Algorithm Development: Design and implement algorithms specifically tailored for quantum computing environments to solve complex problems more efficiently than classical counterparts.
- Quantum System Design: Develop and optimize quantum systems and architectures, ensuring their functionality and scalability for practical applications.
- Quantum Communication Protocols: Create and analyze protocols for secure quantum communication, ensuring the integrity and confidentiality of transmitted information.
- Research and Development: Conduct theoretical and experimental research to explore new quantum phenomena and their potential applications in various fields.

Relevant job roles include Quantum Software Engineer, Quantum Research Scientist, Quantum Cryptography Specialist, Quantum Systems Architect, Quantum Algorithm Developer, and others.

3.1.2.4 UG6–Robotics and Automation Engineering

This unit group focuses on the design, development, and implementation of robotic systems and automation technologies that enhance operational efficiency and productivity across various industries. Professionals in this group leverage interdisciplinary knowledge in mechanical, electrical, and software engineering to create intelligent systems capable of performing tasks autonomously or semi-autonomously. Key responsibilities include:

- System design: develop and design robotic systems and automation solutions tailored to specific applications and industry needs.
- Programming and control: write and implement software algorithms for controlling robotic systems, ensuring precise and reliable operation.
- Integration: integrate robotic systems with existing processes and technologies, ensuring seamless functionality and communication between components.
- Testing and validation: conduct rigorous testing and validation of robotic systems to ensure they meet performance, safety, and regulatory standards.
- Maintenance and support: provide ongoing maintenance and technical support for robotic systems, troubleshooting issues and implementing improvements as necessary.

Relevant job roles include: Robotics Engineer, Automation Engineer, Control Systems Engineer, Robotics Technician, Embedded Systems Engineer, AI Robotics Engineer, Robotics Research Scientist, and others. Here it is important to note that, both UG2 and UG6 involve the integration of hardware components, but UG6 specifically emphasizes robotic systems, while UG2 encompasses a broader range of hardware integration tasks.

3.1.2.5 UG7–Tech Environmentalism

This unit group emphasizes the role of technology professionals in developing and implementing practices that minimize environmental impact and promote sustainability within technological systems. Professionals in this area are responsible for ensuring that technology solutions are designed and operated in an environmentally responsible manner. Key responsibilities include:

- Sustainable Technology Design: Develop and implement technology solutions that prioritize energy efficiency, resource

conservation, and minimal environmental impact throughout their lifecycle.
- Energy System Optimization: Focus on improving the efficiency of energy storage systems (such as batteries) and optimizing energy consumption in CPUs, GPUs, and other electronic components. This includes analyzing and reducing waste to enhance sustainability.
- E-Waste Management: Design and manage programs for the responsible disposal and recycling of electronic waste, promoting circular economy principles within the tech sector.
- Green IT Practices: Advocate for and implement green IT initiatives, such as virtualization, cloud computing, and energy-efficient data centers, to reduce the carbon footprint of technology operations.

Relevant job roles include: Sustainability Engineer, Environmental Technologies Compliance Specialist, Green IT Consultant, Electronic Waste Management Coordinator, Technology Environmental Analyst, Energy Efficiency Analyst, among others.

Some intersections can be found in UG7, UG6 and UG2 job vacancies. However, while UG7 is dedicated to promoting sustainable technology practices, UG6 focuses on automation and robotics for operational efficiency, and UG2 addresses the integration of hardware components, highlighting their distinct roles within the technological landscape.

3.2 MG2–Infrastructure

The Infrastructure major group encompasses professionals responsible for the design, implementation, and management of the foundational technologies that support IT systems and services. These professionals ensure that the underlying infrastructure is robust, scalable, and secure, enabling organizations to operate efficiently and effectively in a technology-driven environment. MG2 is divided into two sub-major groups: Architecture (SM3) and Networking (SM4).

3.2.1 SM3–Architecture

The Architecture sub-major group focuses on the strategic design and planning of IT systems and frameworks that align with organizational goals. Professionals in this group are tasked with creating comprehensive architectural solutions that integrate various technologies and ensure optimal performance. Thus, SM3 consists of two unit groups: IT Architecture (UG8) and Networks and Communications Architecture (UG9).

3.2.1.1 UG8–IT Architecture

This unit group specializes in the design and implementation of IT architectures that support business processes and technology initiatives. Professionals in this group are responsible for creating scalable and flexible architectures that facilitate the integration of various IT components. Key responsibilities include:

- Architectural design: develop and document architectural frameworks that define the structure and interactions of IT systems.
- Technology evaluation: assess and recommend technologies that align with architectural goals and business requirements.
- Integration strategy: formulate strategies for integrating disparate systems and technologies to ensure seamless operation.
- Compliance and standards: ensure that architectural designs adhere to industry standards and regulatory requirements.

Relevant job roles include IT Architect, Solutions Architect, Technical Architect, Infrastructure Architect, and others.

3.2.1.2 UG9–Networks and Communications Architecture

This unit group focuses on the design and optimization of network architectures that facilitate effective communication and data exchange within and between organizations. Professionals in this area are responsible for ensuring that network infrastructures are resilient, secure, and capable of supporting organizational needs. Key responsibilities include:

- Network design: create and implement network architectures that optimize performance and reliability.
- Security architecture: develop security frameworks to protect network infrastructures from threats and vulnerabilities.
- Capacity planning: analyze and forecast network capacity requirements to ensure scalability and performance.

Relevant job roles include Network Architect, Communications Architect, and others.

3.2.2 SM4–Networking

The Networking sub-major group encompasses professionals who specialize in the implementation and management of network infrastructures that enable connectivity and communication across systems. This group focuses on both physical and cloud-based networking solutions. Thus, SM4 consists of two unit groups: Physical Networking (UG10) and Cloud Networking (UG11).

3.2.2.1 UG10–Physical Networking

This unit group is dedicated to the design, installation, and maintenance of physical network infrastructures, including cabling, switches, routers, and other hardware components. Professionals in this area ensure that physical networks are reliable and efficient. Key responsibilities include:

- Network installation: oversee the installation of physical network components, ensuring adherence to design specifications.
- Troubleshooting and maintenance: diagnose and resolve issues related to physical network components to ensure continuous operation.
- Performance monitoring: monitor network performance and implement improvements to optimize efficiency.

Relevant job roles include Network Engineer, Network Technician, Field Network Technician, Network Support Specialist, and others.

It is possible to find some intersections between UG10 and UG9, as well as between UG10 and UG1. It should be considered that, UG10 specializes in the implementation and upkeep of physical network components, whereas UG9 concentrates on designing and optimizing network architectures to enhance communication and data exchange within and between organizations. In addition, UG10 also emphasizes the operational aspects of networking, ensuring seamless communication across systems, whereas UG1 delves into the foundational design of electronic circuits, which are critical for the performance of individual devices.

3.2.2.2 UG11–Cloud Networking

This unit group focuses on the design, implementation, and management of cloud-based networking solutions that facilitate connectivity and data exchange in cloud environments. Professionals in this area are responsible for ensuring that cloud networks are secure, scalable, and efficient. Key responsibilities include:

- Cloud network design: develop and implement cloud networking architectures that support organizational needs.
- Security management: implement security measures to protect cloud networks from threats and vulnerabilities.
- Performance optimization: analyze and optimize cloud network performance to ensure reliability and efficiency.
- Integration with on-premises systems: facilitate the integration of cloud networks with existing on-premises infrastructures.

Relevant job roles include Cloud Network Engineer, Cloud Solutions Architect, Cloud Infrastructure Engineer, Cloud Networking Specialist, and others.

3.3 MG3–Development

The Development major group encompasses professionals involved in the design, development, validation, and deployment of software systems across various platforms and technologies. It has five sub-major groups: Software Architecture (SM5), Software Development (SM6), Validation and Verification (SM7), Operations (SM8), and Experience (SM9).

3.3.1 SM5–Software Architecture

Professionals in the Software Architecture sub-major group are responsible for defining the structure and organization of software systems. They ensure that the architecture aligns with business goals and technical requirements, facilitating scalability, maintainability, and performance. Thus, SM5 consists of two unit groups: System and Enterprise Architecture (UG12) and Application Architecture (UG13).

3.3.1.1 UG12–System and Enterprise Architecture

This unit group focuses on the design and definition of software architecture specifically for conventional and enterprise software systems. Professionals in this group are responsible for creating architectural models that guide the development and integration of software applications within an organization, ensuring that they align with business objectives and technical requirements. Key responsibilities include:

- Architecture definition: define the overall architecture of enterprise software systems, ensuring that it meets business needs and integrates seamlessly with existing systems.
- Technology evaluation: evaluate and select appropriate software technologies and platforms that align with the architectural vision and business objectives.
- Scalability and performance: ensure that the defined architecture supports scalability, maintainability, and performance, allowing the software systems to grow and adapt to changing business needs.
- Architectural review: conduct architectural reviews and assessments to ensure compliance with established standards and best practices, identifying areas for improvement and optimization.

Relevant job roles include: Enterprise Architect, System Architect, Business Architect, and others. It is important to note that, while UG12 highlights the specific focus of enterprise architects on software solutions, UG8 encompasses a broader scope that includes IT architects in managing the overall IT landscape.

3.3.1.2 UG13–Application Architecture

This unit group specializes in the design and development of application architectures that define how software applications are structured and interact with each other and with external systems. Professionals in this group focus on creating scalable, maintainable, and high-performance application architectures that meet both functional and non-functional requirements. They ensure that applications are designed to integrate seamlessly with existing systems and adhere to best practices in software development. Key responsibilities include:

- Application Design: Create architectural designs that outline the structure and components of software applications.
- Integration Planning: Develop strategies for integrating applications with other systems and services, ensuring smooth data flow and interoperability.
- Performance Optimization: Analyze and optimize application performance to ensure responsiveness and efficiency under varying loads.

Relevant jobs include: Software Architect, Application Architect, Integration Architect, Cloud Application Architect, and others.

Here is important to note that, UG12 and UG13 both focus on architectural aspects but operate at different levels. UG12 addresses the overarching structure and integration of all IT systems within an organization, ensuring that various systems work cohesively to support business goals. Professionals in this

group define the architecture that governs interactions between different systems and processes across the enterprise. In contrast, UG13 specifically focuses on the design and structure of individual software applications, ensuring they are scalable, maintainable, and optimized for performance. This group emphasizes how applications interact with each other and integrate with external systems. Thus, while UG12 provides a holistic view ensuring that all systems within an organization work cohesively to support strategic goals, UG13 zooms in on the architectural considerations of individual applications, highlighting their distinct roles and responsibilities.

3.3.2 SM6–Software Development

The Software Development sub-major group encompasses professionals involved in the creation of software applications across various domains, including web, mobile, and enterprise applications. Thus, SM6 consists of four unit groups: Web Dev (UG14), Mobile, Games and Wearables Dev (UG15), Enterprise Application (UG16), and IoT Solutions (UG17).

3.3.2.1 UG14–Web Dev

This unit group focuses on the development of web-based applications, including front-end and back-end components. Professionals in this group work to create responsive and user-friendly web applications that meet the needs of users and businesses. Key responsibilities include:

- Front-end Development: Implement the client-side functionality of web applications using modern web technologies such as HTML, CSS, and JavaScript frameworks.
- Back-End Development: Develop server-side logic, APIs, and database interactions to support the functionality of web applications.
- Performance Optimization: Analyze and optimize web application performance to ensure fast load times and responsiveness.
- Cross-Browser Compatibility: Ensure that web applications function correctly across different browsers and devices, maintaining a consistent user experience.

Relevant job roles include: Software Engineer, Web Developer, Front-End Developer, Back-End Developer, Full-Stack Developer, and others. It is important to note that, professionals in this group emphasizes a broad approach to software development, allowing for flexibility in various web technologies and frameworks.

3.3.2.2 UG15–Mobile, Games and Wearables Dev

This unit group specializes in the development of mobile applications, video games, and wearable technology, focusing on creating engaging and interactive experiences for users across various platforms. Professionals in this group leverage various technologies and frameworks to deliver high-quality applications that meet user expectations. Key responsibilities include:

- Mobile application development: design and develop applications for mobile platforms, including iOS and Android, ensuring optimal performance and user experience.
- Game development: create and implement game mechanics, graphics, and user interfaces for video games, focusing on gameplay and user engagement.
- Wearable technology development: design and develop applications for wearable devices, ensuring seamless integration with mobile platforms and providing unique user experiences.
- Cross-platform development: utilize frameworks and tools to develop applications that function seamlessly across multiple platforms and devices.
- Performance optimization: analyze and optimize mobile, game, and wearable applications for performance, ensuring smooth operation and responsiveness.

Relevant job roles include: Mobile App Developer, Game Developer, Game Designer, Game Programmer, Wearable App Developer, Cross-Platform Developer, Game Designer, and others.

3.3.2.3 UG16–Enterprise Application

This unit group focuses on the development of large-scale enterprise applications that support business processes and operations. Professionals in this group ensure that applications are robust, secure, and scalable, meeting the complex needs of organizations. Key responsibilities include:

- Business requirements analysis: analyze business requirements and translate them into technical specifications for enterprise applications.
- System integration: develop and integrate enterprise applications with existing systems, ensuring seamless data flow and interoperability.
- Robotic process automation (RPA): design and implement RPA solutions to automate workflows, reducing manual effort and increasing efficiency.

Relevant job roles include: Enterprise Application Developer, Business Analyst, Systems Integrator, Application Support Specialist, Technical Consultant, RPA Developer, and others.

Here, it is important to note that, while UG14 focuses on the development of web-based applications that cater to a broad audience and user experience, UG16 specifically addresses the creation of large-scale applications tailored to meet the complex needs of organizations, emphasizing integration, security, and business process support.

3.3.2.4 UG17–IoT and embedded solutions

This unit group specializes in the development of Internet of Things (IoT) solutions that enhance connectivity and data exchange between devices, including embedded systems. Professionals in this group work to create applications and systems that leverage IoT technologies and embedded solutions to enable real-time monitoring, control, and automation. Key responsibilities include:

- IoT application development: design and develop applications that connect and manage IoT devices, ensuring seamless data communication and user interaction.

- Device integration: implement solutions that integrate various IoT devices and embedded systems, enabling them to work together effectively.
- Security implementation: ensure that IoT and embedded solutions are secure, protecting devices and data from unauthorized access and vulnerabilities.
- Performance optimization: analyze and optimize the performance of IoT applications and embedded systems to ensure reliability and efficiency in diverse operational environments.

Relevant job roles include: IoT Developer, IoT Solutions Architect, Embedded Systems Engineer, and others. Here it is important to note that there are potential intersections between UG2, UG6 and UG17 due mainly to overlapping responsibilities in job offers related to hardware integration and system functionality.

Therefore, while UG2 encompasses a broad range of hardware integration tasks across various electronic devices and systems, UG17 specifically targets the connectivity and data exchange between IoT devices, emphasizing real-time monitoring, control, and automation. Professionals in UG17 are expected to possess in-depth knowledge of IoT protocols, data communication standards, and security measures tailored to IoT environments, setting them apart from those in UG2, who concentrate on ensuring compatibility and functionality across diverse hardware systems without a specific focus on IoT applications.

In contrast, UG17 and UG6 may intersect in job requirements involving the automation of IoT devices, yet they maintain distinct areas of expertise. UG6 is primarily focused on the development of intelligent systems designed to execute tasks independently or with minimal human intervention. While UG6 may incorporate IoT components, its core emphasis lies in robotics and control systems, rather than the specific functionalities and applications of IoT solutions. Consequently, professionals in UG6 are expected to have expertise in robotics and automation processes, which may not necessarily include the specialized knowledge required for developing and managing IoT systems, thereby highlighting the unique focus of UG17 within the broader technological landscape.

3.3.3 SM7—Operations

The Operations sub-major group focuses on the management and maintenance of IT systems and applications to ensure their reliability, availability, and performance. Professionals in this group are responsible for implementing operational practices that support the deployment, monitoring, and continuous improvement of software solutions. Thus, SM7 consists of two unit groups: Operational Excellence (UG8) and Reliability Engineering (UG19).

3.3.3.1 UG18—Operational Excellence

This unit group specializes in the integration of development and operations practices to enhance collaboration and efficiency in software delivery. It also includes the application of Artificial Intelligence (AI) to improve IT operations. Key responsibilities include:

- Continuous integration/continuous deployment (CI/CD): IMPLEMENT CI/CD pipelines to automate the build, testing, and deployment processes, ensuring rapid and reliable software delivery.
- Monitoring, analyzing, and logging: set up monitoring and logging systems to track application performance and detect issues in real-time including the systematic use of AI-based services.
- Incident management: manage incidents and outages, ensuring timely resolution and minimizing impact on users.

Relevant job roles include: DevOps Engineer, AIOps Engineer, Release Manager, and others.

3.3.3.2 UG19—Reliability Engineering

This unit group focuses on ensuring the reliability and availability of software systems through proactive monitoring, incident management, and performance optimization. Key responsibilities include:

- Reliability assessment: evaluate the reliability of systems and applications, identifying potential risks and areas for improvement.
- Performance tuning: optimize system performance through analysis and adjustments to configurations, code, and infrastructure.
- Incident response: develop and implement incident response plans to address system outages and performance issues effectively.
- Capacity planning: analyze usage patterns and forecast future capacity needs to ensure systems can handle expected loads.

Relevant job roles include: Reliability Engineer, Site Reliability Engineer (SRE), Performance Engineer, Incident Manager, and others.

It is important to note that UG18 and UG19 both focus on ensuring system performance and reliability but from different perspectives. UG18 emphasizes the integration of development and operations practices to enhance collaboration and efficiency in software delivery. Professionals in this group implement CI/CD pipelines and monitoring systems to streamline processes and improve operational workflows. In contrast, UG19 is dedicated to maintaining the reliability and availability of software systems in production environments. This group focuses on proactive monitoring, incident management, and performance optimization to ensure systems remain operational and meet user expectations. Thus, while UG18 is about enhancing collaboration between development and operations, UG19 centers on the ongoing reliability and performance of systems.

3.3.4 SM8—eXperience

The eXperience sub-major group focuses on the design and enhancement of user experiences across software applications. Professionals in this group are responsible for ensuring that applications are user-friendly, accessible, and engaging, ultimately improving user satisfaction and adoption. Thus, SM8 consists of two unit groups: User Interface and Experience (UG20), and Interaction Design (UG21).

3.3.4.1 UG20–User Interface and Experience

This unit group specializes in user interface (UI) and user experience (uX) design, focusing on creating visually appealing and intuitive interfaces that enhance user interaction with applications. Key responsibilities include:

- User research: conduct research to understand user needs, behaviors, and pain points, informing design decisions.
- Wireframing and prototyping: create wireframes and prototypes to visualize and test design concepts before implementation.
- Visual design: develop the visual elements of the user interface, including layout, color schemes, typography, and iconography.
- Usability testing: conduct usability tests to evaluate the effectiveness of designs and gather feedback for improvements.

Relevant job roles include: UI Designer, uX Designer, User Researcher, and others.

3.3.4.2 UG21–Interaction Design

This unit group focuses on the design of interactions within applications, addressing how users engage with interface elements and how these interactions can be optimized to enhance the overall user experience. Professionals in this group aim to create intuitive and efficient interactions that facilitate seamless navigation and usability. Key responsibilities include:

- User flows: create and prototype interactions that are intuitive and efficient„ allowing the user flows that outline how users interact with the application, identifying critical points and opportunities for improvement.
- Collaboration with UI designers: work closely with UI designers to ensure that interactions align with the aesthetics and functionality of the interface.

Relevant job roles include: Interaction Designer, Usability Specialist, and others. Therefore, while UG20 focuses on overall user experience and interface design, UG21 emphasizes optimizing user interactions within applications.

3.3.5 SM9–Validation and Verification

The Validation and Verification sub-major group focuses on ensuring the quality, reliability, and performance of software applications through systematic testing and quality assurance processes. Professionals in this group are responsible for identifying defects, validating functionality, and ensuring that applications meet specified requirements. Thus, SM9 consists of three unit groups: Software Testing (UG22), Quality Assurance (UG23), and Experience Assurance (UG24).

3.3.5.1 UG22–Software Testing

This unit group specializes in the design and execution of test cases to identify defects and ensure software quality. Professionals in this group utilize various testing methodologies to validate that applications function as intended. Key responsibilities include:

- Test case design: develop detailed test cases based on requirements and specifications to ensure comprehensive coverage of application functionality.
- Test execution: execute test cases and document results, identifying defects and areas for improvement.
- Regression testing: conduct regression testing to ensure that new code changes do not adversely affect existing functionality.
- Automation testing: implement automated testing solutions to improve efficiency and repeatability of test processes.
- Defect tracking: utilize defect tracking tools to log, manage, and prioritize identified issues for resolution.

Relevant job roles include: Software Tester, Test Automation Engineer, Performance Tester, and others.

3.3.5.2 UG23–Quality Assurance

This unit group focuses on establishing quality standards and processes throughout the software development lifecycle. Professionals in this group work to ensure that quality assurance (QA) practices are integrated into all phases of development. Key responsibilities include:

- Quality standards development: define and document quality standards and best practices for software development and testing.
- Process improvement: analyze existing processes and implement improvements to enhance software quality and efficiency.
- Compliance audits: conduct audits to ensure adherence to quality standards and regulatory requirements.
- Risk management: identify potential risks to software quality and develop mitigation strategies to address them.

Relevant job roles include: QA Analyst, QA Manager, Process Improvement Specialist, Technical Writer, and others.

Given that software testing and reliability are essential components of quality assurance, the responsibilities of UG23 professionals can sometimes be confused with those of UG22 and UG19 professionals. UG19 professionals prioritize the ongoing reliability and performance of systems in production, addressing issues such as uptime and system failures. UG22 professionals, on the other hand, focus on validating software through testing to ensure it meets defined standards. In contrast, UG23 professionals strive to cultivate a culture of quality that permeates the entire software development lifecycle, ensuring that products meet all specified requirements before deployment.

3.3.5.3 UG24–Experience Assurance

This unit group focuses on ensuring the quality and effectiveness of user experiences across software applications. Professionals in this group are responsible for implementing strategies and processes that guarantee a consistent and high-quality user experience, ultimately enhancing user satisfaction and loyalty. Key responsibilities include:

- Quality Standards Development: Establish and document quality standards for user experience, ensuring that all applications meet these benchmarks.
- Experience Testing: Conduct thorough testing of user experiences to identify issues and ensure that applications function as intended from a user perspective.
- User Feedback Integration: Gather and analyze user feedback to inform continuous improvement efforts and ensure that user needs are met.
- Performance Monitoring: Monitor user interactions and application performance to identify areas for enhancement and ensure a seamless experience.

Relevant job roles include: XA (eXperience Assurance) Developer, XA Specialist, User Experience Tester, Experience Quality Manager, and others.

It is important to consider that UG20 and UG24 both focus on user experience but from different angles. UG20 is dedicated to the design of user interfaces (UI) and user experiences (uX), emphasizing the creation of visually appealing and intuitive interfaces that enhance user interaction with applications. Professionals in this group conduct user research, wireframing, and usability testing to ensure that applications meet user needs effectively. In contrast, UG24 focuses on ensuring the quality and effectiveness of user experiences across software applications. This group implements strategies and processes to evaluate and enhance user satisfaction, gathering feedback and monitoring user interactions to identify areas for improvement. Thus, while UG20 is primarily concerned with the design aspects of user interfaces, UG24 is about assessing and ensuring the overall quality of user experiences, highlighting their distinct roles and responsibilities within the realm of user experience design.

3.4 MG4–Data

Professionals in this category are crucial for handling data responsibilities, encompassing collection, organization, analysis, interpretation, and management. Their work supports organizations in making informed decisions. By identifying market trends and enhancing operational processes, these experts use advanced analytical tools and methodologies to derive insights, promoting innovation via data-driven strategies. This approach is pivotal in the shift from Industry 4.0 to Industry 5.0, where efficient data management bolsters collaboration between humans and technology. MG4 is formed by three sub-major groups: Data Collection and Management (SM10), Data Analysis and Insights (SM11), and AI Strategies and Engineering (SM12).

3.4.1 SM10–Data Collection and Management

This sub-major group encompasses roles focused on data collection, organization, and maintenance. Responsibilities include database management and ensuring data quality, security, and compliance across traditional and big data environments. SM10 consists of two unit groups: Databases (UG25) and Big Data (UG26).

3.4.1.1 UG25–Databases

This unit group focuses on designing, implementing, maintaining, and optimizing database systems. Professionals ensure that databases remain efficient, secure, and accessible, leveraging various database management systems for data storage, organization, and retrieval. Key responsibilities include:

- Database design: structuring databases to ensure optimal performance and scalability.
- Performance optimization: implementing strategies to enhance database speed and efficiency, including indexing, query optimization, and load balancing.
- Security management: ensuring data protection through mechanisms such as encryption, access controls, and regular audits.
- Backup and recovery: establishing processes for data backup and disaster recovery to protect against data loss.
- System monitoring and maintenance: regularly monitoring database systems to identify and troubleshoot issues proactively, as well as deal with support of database systems, ensuring they run efficiently and securely.

Relevant job roles include Database Support Technicians, Database Administrator, Data Manager, SQL Developer, Data Warehouse Specialist, Database Security Analyst, Data Migration Specialist, and others.

3.4.1.2 UG26–Big Data

This unit group is dedicated to managing, processing, and analyzing the vast volumes of data characteristic of Big Data environments. It emphasizes the use of Big Data technologies to extract meaningful insights and facilitate data-driven decision-making. Core responsibilities include:

- Data management: handling large datasets using big data technologies like Hadoop, Spark, and NoSQL databases.
- Advanced analytics: employing Statistical and Machine Learning techniques to analyze Big Data and generate actionable insights.
- Storage solutions: designing and managing scalable storage solutions that ensure data accessibility and security.
- Innovation and research: continuously exploring and adopting new Big Data tools and methodologies to stay ahead of technological trends and improve data handling efficiency.

Key roles include Big Data Analyst, Hadoop Developer, Big Data Consultant, Big Data Engineer, Streaming Data Engineer, among others.

3.4.2 SM11–Data Analysis and Insights

This sub-major group includes roles centered on data analysis to extract insights that inform strategic decision-making. It covers data interpretation, trend analysis, and the development of analytical models. This group is divided into two unit groups: Analytics (UG27) and Science (UG28).

3.4.2.1 UG27–Analytics

This unit group emphasizes in-depth data interpretation and analysis to generate actionable insights. Professionals are responsible for technical data analysis, including gathering, processing, and interpreting data to identify patterns and trends. They employ various analytical methodologies and tools to conduct comprehensive analyses, often converting raw data into insightful visualizations and reports. Key responsibilities include:

- Data interpretation: deep dive into datasets to identify significant trends, patterns, and correlations.
- Visualization: developing charts, graphs, and dashboards to visually represent data insights using tools like Tableau, Power BI, or others.
- Statistical analysis: applying statistical techniques to quantify insights and validate hypotheses.
- Report and strategic recommendations: producing detailed reports that communicate analytical findings to stakeholders to support business strategies and decisions.

Some key roles include Data Analyst, Business Intelligence Analyst, Reporting Analyst, Market Research Analyst, Customer Insights Analyst, Data Visualization Specialist, etc.

3.4.2.2 UG28–Science

This unit group centers on applying statistical methods and scientific principles to analyze complex datasets and extract valuable insights. Professionals are tasked with designing experiments, performing detailed statistical analyses, and building predictive models. Their work relies on advanced statistical techniques and scientific approaches to guide decision-making and foster innovation. Main responsibilities include:

- Experimental design: designing experiments and studies to collect data in a systematic and scientifically valid manner.
- Research-based analysis: conducting in-depth analyses using statistical software to interpret results and validate hypotheses.
- Learning-based modeling: developing and applying statistical and Machine Learning models to analyze data and make predictions aiming to obtain relevant information for strategic decisions.
- Communication of findings: presenting complex statistical concepts and results in a clear and understandable manner to stakeholders, often through reports and visualizations.
- Research and development: engaging in research activities to advance methodologies and improve analytical techniques within the field.

Key roles include Statistician, Biostatistician, Quantitative Analyst, Operations Research Analyst, Data Science Researcher, Data Scientist, and others.

3.4.3 SM12–AI Strategies and Engineering

This sub-major group integrates strategic planning with the technical implementation of AI and Data Engineering initiatives. It leads the design, development, and deployment of AI solutions and data infrastructures to support advanced analytics and intelligent systems. By merging strategy with execution, this group enables organizations to use AI and Big Data technologies effectively to drive innovation and meet strategic objectives. This group is divided into two unit groups: AI and Data Engineering (UG29) and AI and Data Architecture (UG30).

3.4.3.1 UG29–AI and Data Engineering

Focused on the practical implementation and operationalization of AI and data applications. It emphasizes the creation of robust data pipelines, systems integration, and the deployment of Machine Learning (ML), Deep Learning (DL), Large-Language Models (LLMs), or other AI-based models at scale. The primary responsibilities identified for this group are:

- Model development: building, training, and fine-tuning complex ML, DL or LLMs using frameworks like TensorFlow, PyTorch, or similar tools.
- Infrastructure development: designing and implementing scalable data architectures and pipelines that support efficient data processing and model deployment.
- Integration services: ensuring seamless integration of various data sources and AI systems, fostering a unified data ecosystem.
- Model deployment: collaborating with data scientists to operationalize AI models, ensuring they are production-ready and maintainable.
- Automation and optimization: utilizing automation tools to streamline data processing and model management, enhancing system performance and reliability.

Some key roles include Data Engineer, AI Engineer, Machine Learning Engineer, Deep Learning Engineer, LLM Engineer, AI Operations Engineer, Blockchain Developer, and others. It is important to consider that, professionals in UG29 often leverage Big Data technologies to enhance machine learning and deep learning model development and deployment. Unlike UG26, which focuses primarily on managing and processing vast datasets, UG29 emphasizes the practical implementation of AI solutions, integrating advanced analytics with operational strategies to drive business outcomes.

3.4.3.2 UG30–AI and Data Architecture

Centered on the strategic design and structuring of AI and data systems. This unit group plays a critical role in conceptualizing and designing the overarching frameworks that host AI applications and data processes. It emphasizes creating scalable, robust, and efficient system architectures that meet both current needs and anticipate future organizational demands. The primary responsibilities identified for this group are:

- System framework design: crafting high-level designs and blueprints that define the structure and integration of AI and data systems within the organization.
- Strategic alignment: ensuring that architecture aligns with business objectives and strategic goals, facilitating seamless integration with existing and future technological infrastructures.

- Scalability and flexibility planning: designing architectures that can easily scale and adapt to accommodate evolving technologies and growing data requirements.
- Performance and efficiency optimization: making high-level decisions on technologies and methodologies to enhance overall system performance.
- Security and compliance: establishing architectural guidelines to ensure system security and regulatory compliance throughout the entire data lifecycle.

Examples of key roles are AI Architect, Data Architect, Cognitive Architect, Deep Learning Infrastructure Architect, Cloud Data Architect, and others.

It is important to note that, UG29 and UG30 both focus on AI and data but serve different purposes within an organization. UG29 is centered on the practical implementation and operationalization of AI solutions and data applications. Professionals in this group are responsible for building, training, and deploying machine learning models, as well as creating robust data pipelines and ensuring seamless integration of data sources. In contrast, UG30 focuses on the strategic design and structuring of AI and data systems. This group emphasizes creating scalable and efficient architectures that align with business objectives and facilitate the integration of AI technologies. Thus, while UG29 is hands-on and operational, dealing with the execution of AI projects, UG30 is concerned with high-level design and strategic alignment, highlighting their distinct roles and responsibilities in the AI and data landscape.

3.5 MG5–Management

The Management major group encompasses various professions related to the management of Information Technology (IT), Systems, and Data and AI. This group focuses on ensuring that technology and data resources are effectively aligned with organizational goals and strategies. Thus, MG5 is formed by three sub-major groups: IT Management (SM13), Systems Management (SM14) and Data and AI MAnagement (SM15).

3.5.1 SM13–IT Management

This sub-major group focuses on the management of IT resources, projects, and services to ensure that they meet the needs of the organization and its stakeholders. Thus, SM13 is formed by two unit groups: IT Project Management (UG31) and IT Service Management (UG32).

3.5.1.1 UG31–IT Project Management

This unit group specializes in the planning, execution, and monitoring of IT projects, ensuring that they are completed on time, within scope, and within budget. Key responsibilities include:

- Project planning: develop project plans that outline objectives, timelines, resources, and budgets.
- Risk management: identify potential risks and develop mitigation strategies to minimize their impact on project success.
- Stakeholder communication: maintain clear communication with stakeholders throughout the project lifecycle to ensure alignment and manage expectations.
- Performance monitoring: track project progress and performance against established metrics, making adjustments as necessary.

Relevant job roles include: Project Manager, Scrum Master, Program Manager, and others.

3.5.1.2 UG32–IT Service Management

This unit group focuses on the management of IT services to ensure they meet the needs of users and the organization. Key responsibilities include:

- Service design: develop and implement service designs that align with user needs and organizational objectives.
- Service delivery: ensure that IT services are delivered effectively and efficiently, meeting established service level agreements (SLAs).
- Incident management and continuous improvement: manage incidents and service requests, ensuring timely resolution and minimal disruption to users, aiming to identify opportunities for service improvement.
- User training and support: provide training and support to users to ensure they can effectively utilize IT services.

Relevant job roles include: IT Service Manager, Service Desk Manager, ITIL Consultant, and others.

3.5.2 SM14–Systems Management

This sub-major group focuses on the administration and optimization of IT systems to ensure they operate efficiently and effectively. Here, SM14 is formed only one unit group: Systems Administration (UG33).

3.5.2.1 UG33–Systems Administration

This unit group specializes in the administration and maintenance of IT systems, ensuring their reliability and performance. Key responsibilities include:

- System configuration: install, configure, and maintain operating systems and software applications.
- Monitoring and performance tuning: monitor system performance and make adjustments to optimize efficiency.
- Backup and recovery: implement backup and recovery procedures to protect data and ensure business continuity.
- User management: manage user accounts and permissions, ensuring appropriate access to systems and resources.
- Troubleshooting: diagnose and resolve system issues, providing timely support to users.

Relevant job roles include: Systems Administrator, Network Administrator, and others.

3.5.3 SM15—Data and AI Management

This sub-major group focuses on the management of data resources and the implementation of AI solutions to support organizational objectives. Thus, SM15 is formed by two unit groups: Data Management (UG34) and AI Project Management (UG35).

3.5.3.1 UG34—Data Management

This unit group specializes in the governance, quality, and security of data within the organization. Key responsibilities include:

- Data governance: establish policies and procedures for data management, ensuring compliance with regulations.
- Data quality management: implement processes to ensure the accuracy, consistency, and reliability of data.
- Data security: develop and enforce security measures to protect sensitive data from unauthorized access.
- Data lifecycle management: manage the lifecycle of data from creation to archiving or deletion.

Relevant job roles include: Data Manager, Data Governance Analyst, Data Privacy Officer, and others.

3.5.3.2 UG35—AI Project Management

This unit group focuses on the management of projects related to artificial intelligence, from conception to implementation. Key responsibilities include:

- AI Strategy Development: Define and implement strategies for AI projects that align with business objectives.
- Project Planning: Develop project plans that outline objectives, timelines, resources, and budgets for AI initiatives.
- Stakeholder Communication: Maintain clear communication with stakeholders throughout the project lifecycle to ensure alignment and manage expectations.
- Performance Monitoring: Track project progress and performance against established metrics, making adjustments as necessary.

Relevant job roles include: AI Project Manager, AI Product Manager, Machine Learning Project Manager, and others.

4 Discussion

The introduction of BEET marks a significant advancement as a framework to support the task of IT jobs classification, since it represents a detailed tool adapted to the evolving demands of the technology sector in the context of Industry 5.0. This section discusses the implications of this taxonomy, insights gained from the dataset analysis, and the broader context of challenges and reliability.

4.1 Descriptive analysis

The labeled dataset for BEET comprises 389 IT job postings in English, collected globally between 2023 and 2025. These job postings were sourced from 221 unique companies of varying sizes across different regions. Given that company names were anonymized, their sizes were mapped according to the LinkedIn classification system.[1] In this system, category *A* is reserved for individual workers, category *B* represents companies with 1 to 10 employees, *C* includes companies with 11 to 50 employees, *D* corresponds to those with 51 to 200 employees, *E* covers companies with 201 to 500 employees, *F* includes those with 501 to 1,000 employees, *G* represents companies with 1,001 to 5,000 employees, *H* includes organizations with 5,001 to 10,000 employees, and finally, *I* denotes companies with more than 10,000 employees. AAs observed in Figure 3, our dataset is characterized by the predominance of job postings published by companies in size categories *I* and *G*, suggesting a concentration of opportunities in large organizations. Companies in category *B* have only 2 job postings and there are no companies in category *A*. Thus, less than half of the job postings belong to companies *C*, *D*, *E*, *F* and *H*.

As previously mentioned, we aimed to maintain a balanced distribution of job categories within the dataset, as well as a proportional representation of companies publishing job postings. However, due to the technical specificity of certain roles, some job categories emerged more frequently, reflecting the specialization of specific companies in particular areas. Consequently, Figure 4 illustrates that only six companies have between 10 and 19 job postings in our dataset. Moreover, the vast majority of companies have six or fewer job postings.

To account for the global nature of the IT labor market, the job postings in our dataset originate from companies worldwide. Figure 5 presents the top-10 countries with the highest number of job postings. We highlight the significant number of job postings published by companies in the United States of America (USA), which accounts for 263 vacancies, followed by Brazil and Mexico, each with 24 postings. Spain has 13 postings, and the United Arab Emirates (UAE) has 11. The remaining countries in the dataset have 7 or fewer job postings.

On the other hand, Figure 6 provides a clearer understanding of the relationship between the country where job postings were published and the size of the companies. The figure shows that most job postings were made by companies classified as size I and G, primarily in countries recognized as global technology and innovation hubs, such as the USA, the UAE, and the United Kingdom (UK), indicating a correlation between company size and location in technologically advanced regions.

By applying BEET to the labeled data, a deeper understanding of the breadth and scope of the five Major Groups (MGs) can be achieved by identifying interrelated topics, which serve as the foundation for defining the Sub-Major Groups (SMs) and Unit Groups (UGs), allowing for a more robust analysis of employment

1 https://learn.microsoft.com/en-us/linkedin/shared/references/reference-tables/company-size-codes

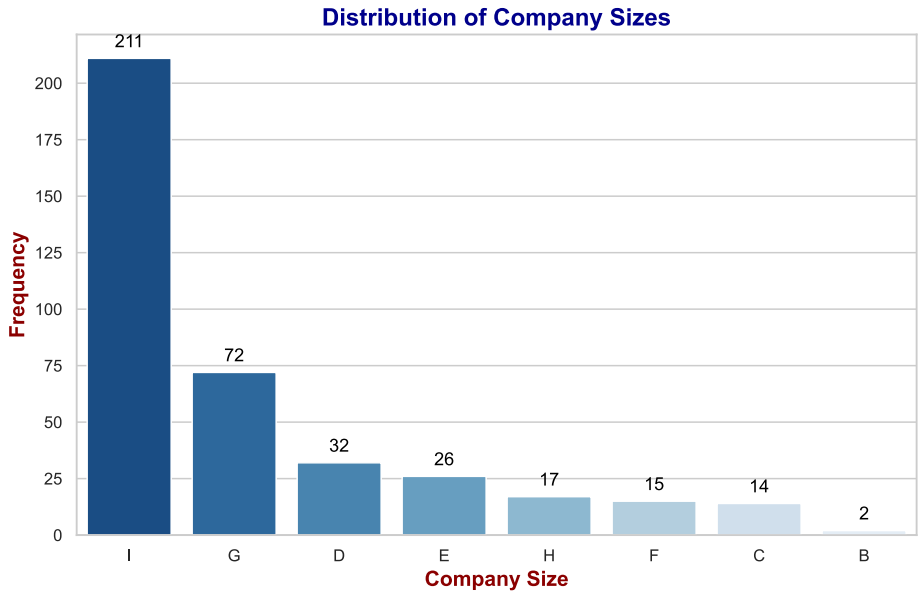

FIGURE 3
Frequency of job postings published by companies according to their size.

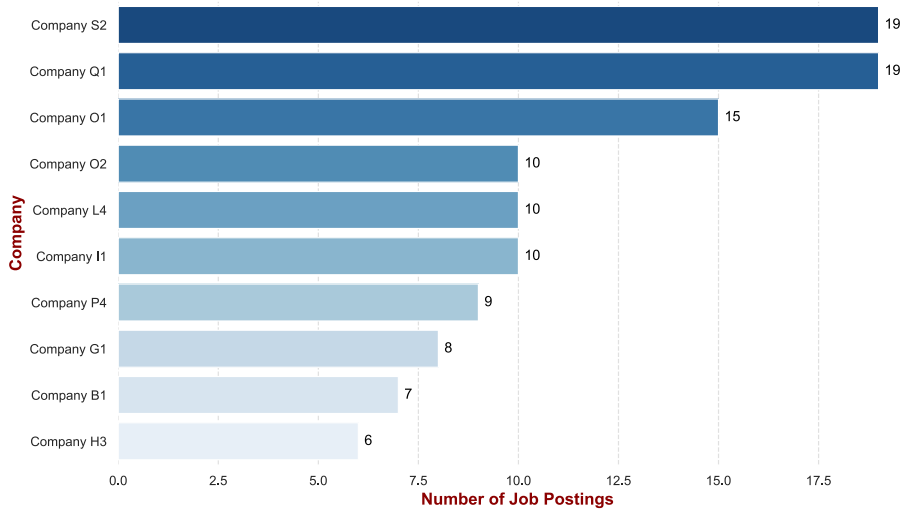

FIGURE 4
Top 10 companies with the most job postings.

trends in the IT sector. his observation is supported by Figure 7, which presents word clouds for each of the five MGs.

We can also analyze the distribution of UGs in relation to the size of the companies that published the job postings, as illustrated in Figure 8. In the figure, it can be observed that UG29 has the highest number of job postings, followed by UG3 and UG28, while UG24, UG21, and UG23 have the fewest postings. Despite this variation, a common trend across most UGs is that job vacancies were predominantly posted by size *I* companies, which may indicate a market preference for large organizations when offering job opportunities.

In summary, the descriptive analysis of the BEET dataset reveals significant insights into the landscape of IT job postings across various company sizes and geographical regions. The predominance of larger organizations in the dataset highlights the concentration of opportunities within established companies, particularly in technology and innovation hubs. Furthermore, the variations in job categories and postings underscore the technical specificity of roles within the industry. By leveraging the BEET framework, we can better understand the dynamics of the IT labor market, paving the way for more targeted research and analysis in subsequent sections. This foundational understanding sets the stage for exploring the implications of these findings in the broader context of employment trends and skill requirements in the technology sector.

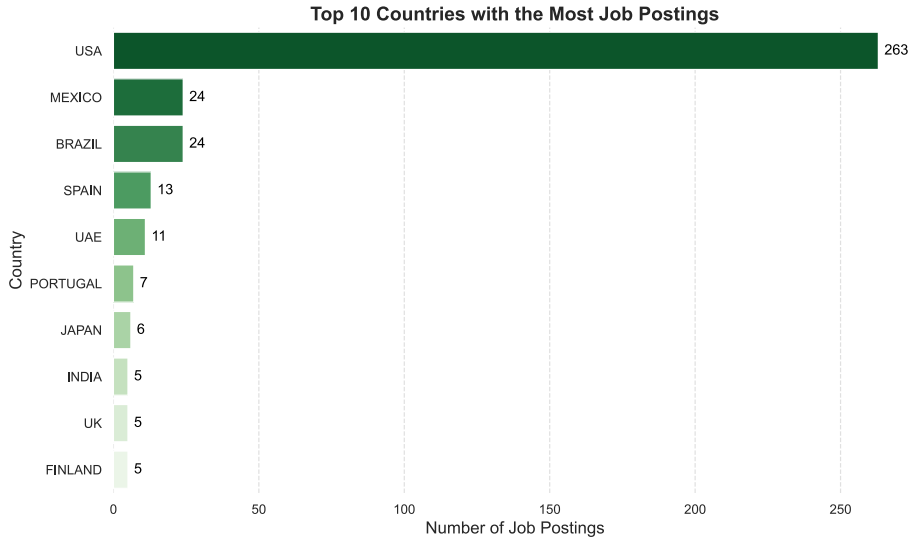

FIGURE 5
Top 10 countries with the highest number of job postings.

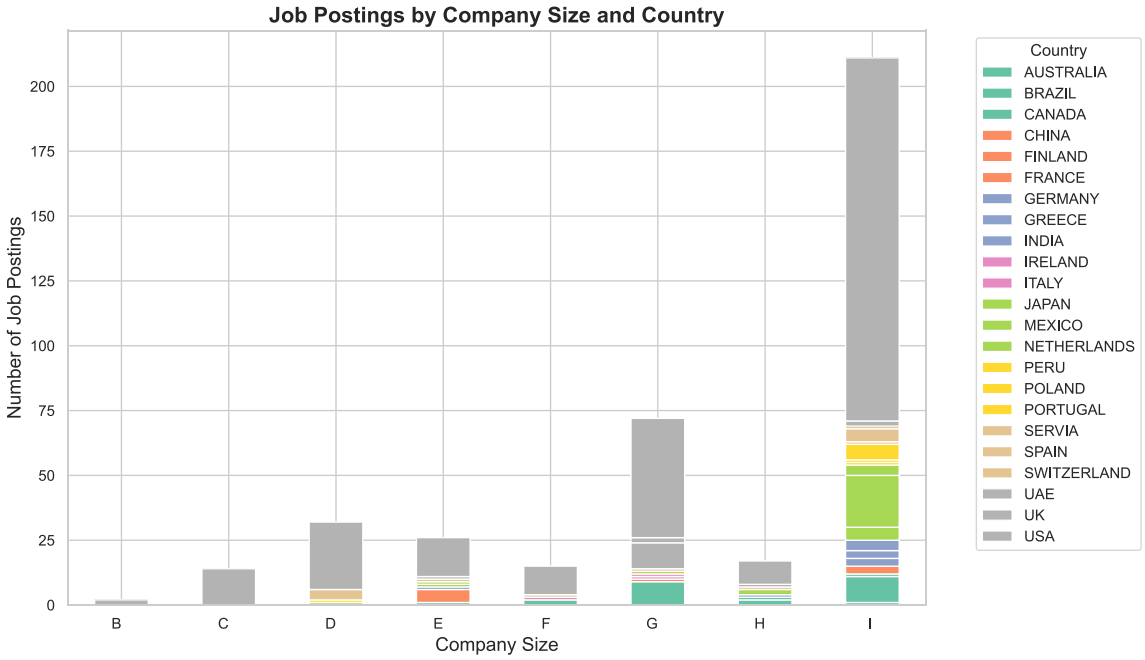

FIGURE 6
Distribution of job postings by company size and country of publication.

4.2 Limitations and future research directions

While BEET represents a significant advancement in the classification of IT jobs, certain limitations must be mentioned. The dataset specifically constructed for BEET's development consists of job postings available in English from various countries worldwide. This linguistic constraint may limit the generalizability of our findings to regions and markets where English is not the primary language. As a result, this selection bias could overlook linguistic and cultural nuances present in job markets that operate in other languages, potentially impacting the comprehensiveness and adaptability of our taxonomy.

Another limitation to consider is the fact that, our dataset was sourced from publicly available job postings, which may introduce a second type of selection bias, as it might not fully capture positions from companies that rely heavily on internal recruitment strategies or confidential postings. As a

FIGURE 7
Word clouds for the five major groups of BEET. **(a)** Word cloud from job postings MG1. **(b)** Word cloud from job postings MG2. **(c)** Word cloud from job postings MG3. **(d)** Word cloud from job postings MG4. **(e)** Word cloud from job postings MG5.

result, certain niche roles or emerging positions that are less frequently advertised online could be underrepresented in our taxonomy.

In this regard, future research will focus on mitigating the biases identified in our dataset to enable further iterations of our framework, ultimately leading to a more robust version of BEET. Additionally, to facilitate its adoption, we plan to develop and deploy machine learning and deep learning models, including Generative Artificial Intelligence (GenAI) models, capable of assimilating BEET and automatically classifying job vacancies. By doing so, we aim to reduce human effort while ensuring greater efficiency and scalability, thus maximizing the intended impact of our approach.

5 Conclusion

This paper presents a novel hierarchical taxonomy for classifying computer jobs within the broader framework of ISCO-08. While existing frameworks like ISCO-08 provide a broad classification, there has been a lack of taxonomies specifically tailored to the IT sector's evolving needs, particularly in the context of Industry 5.0 skills. This paper presents BEET as a potential

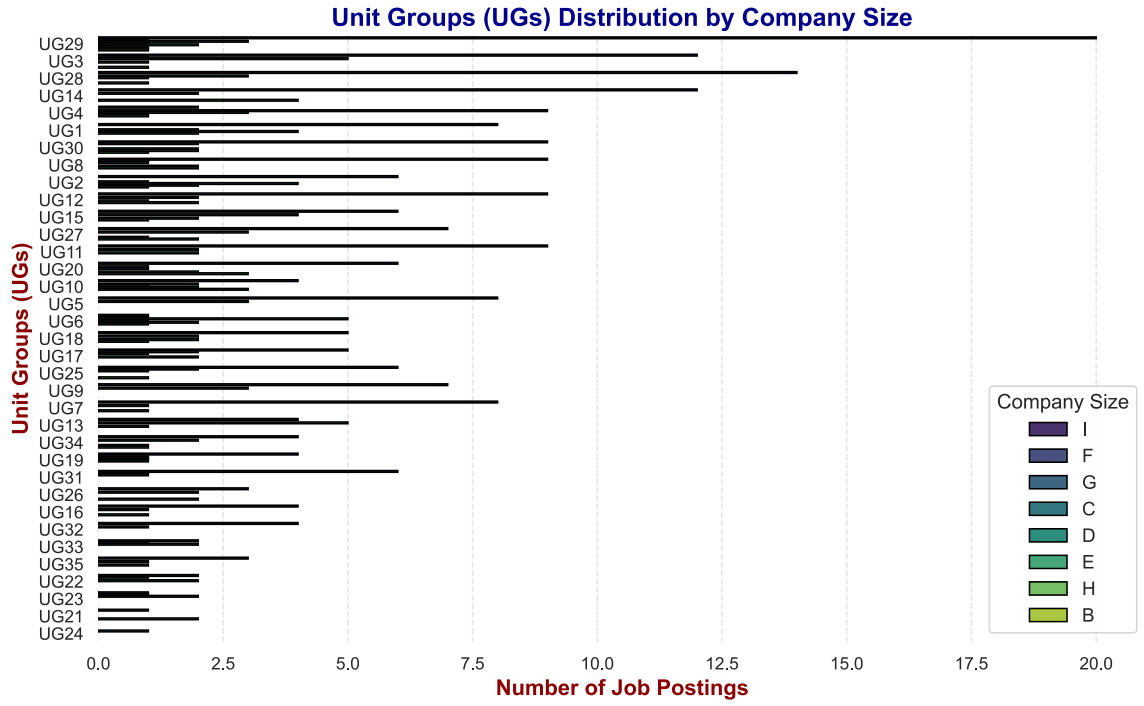

FIGURE 8
Distribution of unit groups by company size and country of publication.

solution to this gap, providing a more granular classification system for IT roles. We introduce Bee-inspired Employment and Expertise Taxonomy (BEET), a hierarchical framework designed to classify IT jobs within the ISCO-08 structure. BEET prioritizes the hard skills required for task execution, focusing primarily on hard skills regardless of the way they are acquired or the seniority level, which aligns with the goal of capturing the core competencies required for job execution rather than hierarchical distinctions.

BEET is hierarchical in nature and is formed by five major groups (MGs), which are further divided into 15 sub-major categories (SMs) and 35 unit groups (UGs). While the structure is designed to classify each job offer into a single UG, the overlapping skill requirements in many IT job postings may result in some roles fitting into more than one UG. In such cases, a detailed job analysis is essential for accurate classification.

By aligning educational efforts with the changing needs of the global IT market, BEET constitutes a solid framework for both analysts and educators, providing essential strategic insights for future workforce development in the rapidly evolving global IT landscape.

Future research should focus on expanding the dataset to encompass a broader range of languages and recruitment sources, thereby enhancing the cross-cultural applicability of BEET. Additionally, integrating qualitative studies that explore the specific needs of diverse job markets could further refine and validate the taxonomy, ensuring its relevance across various global contexts. Furthermore, our immediate research objective is to train machine learning models capable of assimilating BEET and performing the automatic classification of job postings. This approach will reduce human effort while ensuring the adoption and scalability of BEET in real-world applications.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://github.com/jvalverr/beet-it-jobs-taxonomy.

Author contributions

JV-R: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing. FR: Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – review & editing. JN: Validation, Writing – review & editing. ND: Funding acquisition, Methodology, Project administration, Resources, Validation, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This work was partially supported by the São Paulo Research Foundation (FAPESP) through grants 2019/02455-1, 2019/26423-1, 2020/09218-2, 2020/00374-1, and 2020/04965-4. Additionally, funding for

publication was provided by the Writing Lab at the Institute for the Future of Education of Tecnológico de Monterrey.

Acknowledgments

We would like to thank the Writing Lab at the Institute for the Future of Education for their assistance in the publication of this work. We also extend our gratitude to the Computing Department of Tecnologico de Monterrey, Mexico City Campus. Finally, we express our thanks to Isis Fernanda Mascarin and Guisella Ángulo for their invaluable support in the development of BEET, as well as to the entire team of HR analysts, researchers, and data scientists at Visibilia who contributed to this project.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Akah, L. U., Owan, V. J., Alawa, D. A., Ojie, F. C., Usoro, A. A., Dada, O. A., et al. (2022). ICT deployment for teaching in the COVID-19 era: a quantitative assessment of resource availability and challenges in public universities. *Front. Educ.* 7:920932. doi: 10.3389/feduc.2022.920932

Alharbi, F., and Al-Alawi, A. I. (2024). "Labor market prediction using machine learning methods: a systematic literature review," in *2024 ASU International Conference in Emerging Technologies for Sustainability and Intelligent Systems (ICETSIS)* (Manama: IEEE), 478–482. doi: 10.1109/ICETSIS61505.2024.10459632

Apatsidis, I., Georgiou, K., Mittas, N., and Angelis, L. (2021). "A study of remote and on-site ICT labor market demand using job offers from stack overflow," in *2021 47th Euromicro Conference on Software Engineering and Advanced Applications (SEAA)* (Palermo: IEEE), 252–259. doi: 10.1109/SEAA53835.2021.00039

Association for Computing Machinery (2012). *The 2012 ACM Computing Classification System*. Available online at: https://www.acm.org/publications/class-2012 (accessed october 5, 2024).

Australian Bureau of Statistics (2022). *Conceptual Basis of Anzsco*. Report. Available online at: https://www.abs.gov.au/statistics/classifications/anzsco-australian-and-new-zealand-standard-classification-occupations/2022/conceptual-basis-anzsco (accessed october 5, 2024).

Azofeifa, J. D., Rueda-Castro, V., Gonzalez-Gomez, L. J., Gómez-Puente, S. M., Noguez, J., and Caratozzolo, P. (2024). "Unlocking the future of infocomm workforce: A visual ksa matrix taxonomy approach to education and occupational profiles," in *2024 IEEE Global Engineering Education Conference (EDUCON)* (Kos Island: IEEE), 01–09.

Baldwin, T., Clarke, W., Garcia de Macedo, M. M., de Paula, R., and Das, S. (2022). "Better skill-based job representations, assessed via job transition data," in *2022 IEEE International Conference on Big Data (Big Data)* (Osaka: IEEE), 2182–2185.

Barefah, A. (2024). Assessing the alignment of university academic programs with the requirements of saudi arabia's data and business analytics job market. *J. Educ. Busin.* 99, 175–186. doi: 10.1080/08832323.2023.2294356

Butiurca, A. D., and Zancanaro, M. (2021). "What is it like to be a ux designer in italy? An initial analysis of job advertisements to improve training and education in HCI," in *Proceedings of the 14th Biannual Conference of the Italian SIGCHI Chapter, CHItaly '21* (New York: ACM).

Castro Silva, H., and Lima, F. (2017). Technology, employment and skills: a look into job duration. *Res. Policy* 46, 1519–1530. doi: 10.1016/j.respol.2017.07.007

Choi, I. H., Kim, Y. S., and Lee, C. K. (2021). "A study of the classification of IT jobs using LSTM and LIME," in *The 9th International Conference on Smart Media and Applications, SMA 2020* (New York, NY: Association for Computing Machinery), 248–252.

Dobslaw, F., Angelin, K., Öberg, L.-M., and Ahmad, A. (2023). "The gap between higher education and the software industry — a case study on technology differences," in *Proceedings of the 5th European Conference on Software Engineering Education, ECSEE '23* (New York: ACM), 11–21.

FAPESP (2019). *Biblioteca virtual da fapesp*. Available online at: https://bv.fapesp.br/pt/auxilios/105710/beenet-a-solucao-para-o-problema-da-oferta-e-procura-de-emprego/ (accessed october 6, 2024).

Fettach, Y., Ghogho, M., and Benatallah, B. (2022). Knowledge graphs in education and employability: A survey on applications and techniques. *IEEE Access* 10, 80174–80183. doi: 10.1109/ACCESS.2022.3194063

Ghosh, A., Woolf, B., Zilberstein, S., and Lan, A. (2020). "Skill-based career path modeling and recommendation," in *2020 IEEE International Conference on Big Data (Big Data)* (Atlanta, GA: IEEE), 1156–1165.

Hötte, K., Somers, M., and Theodorakopoulos, A. (2023). Technology and jobs: a systematic literature review. *Technol. Forecast. Soc. Change* 194:122750. doi: 10.1016/j.techfore.2023.122750

Instituto Nacional de Estadística y Geografia (2019). *Sistema Nacional de Clasificación de Ocupaciones, 2019*. Available online at: https://www.inegi.org.mx/app/biblioteca/ficha.html?upc=702825198411 (accessed october 5, 2024).

International Labour Organization (2023). *The International Standard Classification of Occupations (ISCO-08). Companion Guide*. Available online at: https://www.ilo.org/publications/international-standard-classification-occupations-isco-08-companion-guide (accessed october 5, 2024).

Jose Gonzalez-Gomez, L., Margarita Hernandez-Munoz, S., Borja, A., Daniel Azofeifa, J., Noguez, J., and Caratozzolo, P. (2024). Analyzing natural language processing techniques to extract meaningful information on skills acquisition from textual content. *IEEE Access* 12, 139742–139757. doi: 10.1109/ACCESS.2024.3465409

König, R., and Seifert, A. (2022). Digitally savvy at the home office: computer skills of older workers during the COVID-19 pandemic across Europe. *Front. Sociol.* 7:858052. doi: 10.3389/fsoc.2022.858052

Koo, K., and Le, L. (2024). IT capability and innovation. *Technol. Forecast. Soc. Change* 203:123359. doi: 10.1016/j.techfore.2024.123359

Melkumyan, A. (2006). "Overview of job classifications and certifications in the IT sector," in *United States Agency for International Development (USAID), Information Technologies Workforce Supply Assessment, 125*.

Moravánszky, A. (2024). "Swissreview - mapping the requirements engineering job landscape," in *2024 IEEE 32nd International Requirements Engineering Conference (RE)* (Reykjavik: IEEE), 450–456. doi: 10.1109/RE59067.2024.00053

Napierala, J., and Kvetan, V. (2023). *Changing Job Skills in a Changing World*. Cham: Springer International Publishing, 243–259.

Oikonomou, M., Pierri, N., and Timmer, Y. (2023). IT shields: technology adoption and economic resilience during the COVID-19 pandemic. *Labour Econ.* 81:102330. doi: 10.1016/j.labeco.2023.102330

Papoutsoglou, M., Ampatzoglou, A., Mittas, N., and Angelis, L. (2019). Extracting knowledge from on-line sources for software engineering labor market: a mapping study. *IEEE Access* 7, 157595–157613. doi: 10.1109/ACCESS.2019.2949905

Senger, E., Zhang, M., van der Goot, R., and Plank, B. (2024). "Deep learning-based computational job market analysis: A survey on skill extraction and classification from job postings," in *Proceedings of the First Workshop on Natural Language Processing for Human Resources (NLP4HR 2024)*, eds. E. Hruschka, T. Lake, N. Otani, and T. Mitchell (New York: ACL), 1–15.

Siddique, A., Butt, G. M., Zahid, A., Naveed, Q. N., and Alouane, M. T.-H. (2024). Analyzing software industry trends to improve curriculum. *IEEE Access* 12, 22510–22523. doi: 10.1109/ACCESS.2024.3362244

Siswipraptini, P. C., Warnars, H. L. H. S., Ramadhan, A., and Budiharto, W. (2023). Information technology job profile using average-linkage hierarchical clustering analysis. *IEEE Access* 11, 94647–94663. doi: 10.1109/ACCESS.2023.3311203

Siswipraptini, P. C., Warnars, H. L. H. S., Ramadhan, A., and Budiharto, W. (2024). personalized career-path recommendation model for information technology students in Indonesia. *IEEE Access* 12, 49092–49105. doi: 10.1109/ACCESS.2024.3381032

Statistics Canada (2021). *National Occupational Classification (NOC) 2021 Version 1.0*. Available online at: https://noc.esdc.gc.ca/ (accessed october 5, 2024).

Ternikov, A. (2022). Soft and hard skills identification: insights from it job advertisements in the cis region. *PeerJ Computer Sci*. 8:e946. doi: 10.7717/peerj-cs.946

Uter, W. (2017). *Classification of Occupations*. Cham: Springer International Publishing, 1–9.

Valverde-Rebaza, J., Góes, F., Noguez, J., and Da Silva, N. C. (2024). "Exploring industry 5.0 skills: a comprehensive taxonomy for IT job classification," in *Proceedings of The 19th World Conference on Continuing Engineering Education, IACEE 2024* (Atlanta, GA: IACEE), 62–65.

Valverde-Rebaza, J., Puma, R., Bustios, P., and Da Silva, N. C. (2018). "Job recommendation based on job seeker skills: an empirical study," in *Proceedings of the First Workshop on Narrative Extraction From Text, volume 2077 of Text2Story 2018* (Grenoble: CEUR Workshop Proceedings). 47–51.

Wang, C., Cui, P., Daneva, M., and Kassab, M. (2018). "Understanding what industry wants from requirements engineers: an exploration of RE jobs in Canada," in *Proceedings of the 12th ACM/IEEE International Symposium on Empirical Software Engineering and Measurement, ESEM '18* (New York: ACM).

Wang, C., Tang, Y., Liang, P., Daneva, M., and van Sinderen, M. (2020). "What industry wants from requirements engineers in china? An exploratory and comparative study on re job ads," in *Proceedings of the 14th ACM / IEEE International Symposium on Empirical Software Engineering and Measurement (ESEM)*, *ESEM '20* (New York: ACM).

World Economic Forum (2023). *Future of Jobs Report 2023*. Available online at: https://www.weforum.org/publications/the-future-of-jobs-report-2023/in-full/ (accessed october 5, 2024).